

VI. OCEAN AND COASTAL RESOURCES

Introduction

Approximately 85 percent of California's residents live and work in coastal counties; these populations will be at risk from a range of climate impacts that are specific to these regions.¹ California's coastal areas are home to unique and threatened ecosystems that offer unmatched recreation and tourism opportunities for people, provide invaluable habitat for rare species, and buffer coastal communities from flood and erosion. Yet, between 1980 and 2003, California's coastal population grew more than any other state's coastal population, increasing by a total of 9.9 million people, or 1,179 persons *every day*.² By 2025, the coastal population is expected to grow – albeit at a slower rate – to over 32 million people.³ Along with people, infrastructure and assets are also concentrated along the coast. According to recent estimates developed for the 2009 California climate change impacts assessment, a 100-year flood event after a 1.4 meter (55 inches) sea-level rise will put 480,000 people at risk and nearly \$100 billion in property.⁴ In addition, California residents and out-of-state visitors make well over 500 million visits to the state's ocean beaches every year. People go to the coast to enjoy sun and sand, the vistas, and the unrivaled diversity of plants and animals that inhabit the region. All of these visits contribute greatly to California's ocean-dependent economy, which is estimated to be \$46 billion per year.⁵

In 2006, the California Climate Change Center reported a historic sea-level rise of 7 inches in the last century and projected an additional rise of 22–35 inches by the end of this century. Since that time numerous other studies have published projected ranges of 7–23 inches,⁶ 20–55 inches,⁷ and 32–79 inches⁸ of sea-level rise for this same period, with the differences in these projections attributable to different methodologies used and how well or whether glacier ice melt is included in the calculations. This report uses the 20–55 inch projection, as it was the best available science at the time of the 2009 impacts assessment. Future sea-level rise estimates will vary based on future GHG emissions.

Much of the damage from this accelerated sea-level rise will likely be caused by an increase in the frequency and intensity of coastal flooding and erosion associated with extreme weather events and storm surges. In addition to sea-level rise, California's coastal and ocean resources are expected to experience additional dramatic changes. These include more severe atmospheric events (e.g., El Niño events); changes in ocean chemistry (e.g., temperature and pH) and estuarine chemistry (e.g., temperature, pH, and salinity); and changes in ecosystem processes (e.g., nutrient upwelling).

While the exact future of the coast is uncertain, one thing is clear: we're going to have to change the way we think about managing our natural assets and human development. Existing laws (such as the California Coastal Act) provide state and local governments with tools for addressing the effects of climate change, but also impose some significant limitations. Laws written in and designed for the 20th century will need to be updated to reflect new ideas about climate change in the 21st century.

Californians will need to make tough decisions about which critical assets we want to protect, which ones can be relocated, which ones will have to be removed, and what is economically reasonable. Development and land-use is already putting stress on coastal ecosystems and resources, constraining their natural ability to adapt to a highly dynamic environment. New development along the coast should be designed and sited to anticipate expected sea-level rise, minimize future hazards, and maintain the biological productivity of the coastal environment. Yet, it will not always be possible to achieve the multiple goals of continued development, protection of critical infrastructure, sustained coastal recreation, and ecosystem protection. For example, shoreline protection structures negatively impact beach access, beach size, shoreline processes, recreation, tourism, and coastal habitats. Ultimately, when these goals are in conflict there will likely be winners and losers. We need to recognize this fact and develop priorities and the regulatory authorities that will allow decisions to be made in a reasonable manner that takes into account numerous factors and interests.

Future Climate Impacts to Oceans and Coastal Resources

A. Increased Temperature and Extreme Events

Air temperatures are expected to rise in coastal California at a slower pace than inland areas due to the cooling influence of the Pacific Ocean.⁹ This may draw greater numbers of Californians to the coast. The implications of this possible migration for the economy, housing market, transportation infrastructure, coastal ecosystems, and quality of life have not been assessed to date but could be significant.

Ocean water temperatures will rise as air temperatures rise, causing changes in marine and coastal species behavior and distribution. Species within California's coastal and ocean environments are adapted for life within a particular range of temperatures.¹⁰ Temperatures above or below optimal range can affect the metabolism, growth, and reproduction of stressed aquatic species.¹¹ As such, temperature is one of the primary environmental factors that determine the geographic range of a species.¹² Shallow coastal waters (e.g., bays and estuaries) will warm sooner than the deeper parts of the oceans, thus warming temperatures should have a direct impact first in the coastal ocean, including bays, estuaries, lagoons, and wetlands. One direct impact of changing water temperatures is a change in coastal water quality because warmer water holds less oxygen.

Increases in water temperatures off the coast of California have already led to a shift in the geographic range of species. As atmospheric and ocean temperatures continue to rise, species that currently have a geographic range from Point Conception south to the Mexican border will begin to shift their geographic range northward up the coast to find ocean temperatures within their physiological range. This has already been observed with the Humboldt squid that used to be an occasional visitor and is now a permanent resident in central California's coastal waters.¹³ Just as on land, non-native/invasive species will migrate from more southern areas adding further displacement pressure on native species and taking hold in ocean and coastal ecosystems disturbed by climate change.¹⁴

Warming can also affect the ocean food web in indirect ways. El Niño patterns or Santa Ana winter wind intensity could significantly alter the nutrient cycling that underpins the marine food web and current species assemblages.¹⁵ Santa Ana winds coincide with cool sea surface temperatures, upwelling, and a spike in biological activity. These winds are projected to decline in intensity, but it is not known how marine nutrient availability and food webs will change.¹⁶

OCEAN AND COASTAL RESOURCES IMPACTS DUE TO WARMING

- Population Changes in Coastal Areas Anticipated
- Public Health Education and Planning Needed for Extreme Heat
- Relocation of Marine Species and Southern and Exotic Species May Become Invasive
- Changes in Marine Food Systems (Upwelling and Nutrient Availability)
- Changes in Commercial and Recreational Ocean Fishery and Economic Impacts

Warmer ocean temperatures together with changed nutrient availability could result in a decrease in fish populations or a shift in the geographic range of harvested species.¹⁷ During the 1997-1998 El Niño, California's commercial squid industry realized the vulnerability of the fishing industry to water conditions. Squid landings (the number or poundage of fish brought to shore by fishermen) decreased from 110,000 metric tons in 1996-1997 to just 1,000 metric tons over the course of the El Niño season.¹⁸ Together with expected changes in coastal estuaries and wetland habitat resulting from sea-level rise (see below), commercial and recreational fish species may experience lower reproductive success and population decline.

While climate change may reduce or shift the habitable range of current fishery species, it may also allow new fish populations to move north. Some of these new species may become economically significant commercial or recreational fish populations (e.g., the Humboldt squid). The net effect upon the marine fishing industry is currently unknown and should be a subject of future study. Transitional costs (e.g., harvesting gear, marketing activity) to adapt to any new fishery would be expected. The health of California's fisheries will depend on each species' adaptive capabilities, the rate and complexity of interactions in the marine food web as a result of climate change, and the state's ability to implement measures to limit catches to sustainable levels and protect coastal habitats.

B. Precipitation Changes and Extreme Events

In California's coastal areas precipitation falls almost exclusively as rain, even in winter. Coastal fog also plays a large role in providing the moisture required for the maintenance of terrestrial coastal ecosystems; changes in coastal fog density will impact coastal forest types. A general pattern of a drying climate over the 21st century could result in rainstorms that are fewer in number, but greater in intensity; and less coastal fog. Changes to the timing and intensity of freshwater input from rainstorms could impact marine and near shore species. Changing precipitation patterns will potentially increase the occurrences of flooding in coastal drainages. In coastal floodplain areas, runoff from land may coincide with the coastal storm surge (also higher due to sea-level rise) and lead to greater flooding risks in the immediate coastal zone.¹⁹

Less frequent but more intense rainfall patterns could have serious consequences on water quality. With an increase in frequency and intensity of wildfires,²⁰ increased runoff and flooding will remain a considerable risk and may also result in higher levels of pollution and sediment runoff. The first flush during storm events is frequently heavily contaminated with toxins deposited on roads, driveways, parking lots and rooftops. Heavy runoff also offers a medium for infectious disease vectors to multiply and spread. Large amounts of runoff may overwhelm the capacity of sewers and sewage treatment plants to absorb and adequately cleanse waters before they reach coastal waters and beaches. Thus, both coastal and marine species and human health are at greater risk in the period following heavy storms (see the Public Health chapter). Infectious diseases in coastal waters and seafood may spread, and invasive species well-suited to more extreme conditions may flourish.²¹ If the intensity of such extreme events increases, both human populations and natural habitats will be exposed to increased stresses and have less time to recover between occurrences.²²

Potentially the most damaging extreme events in coastal California will be winter ocean storms. Past El Niño events have resulted in significant financial damages and exposed large numbers of people to flooding hazards. Climate change will likely exacerbate these impacts with larger waves and higher water levels. These storms will also affect coastal erosion and sediment transport patterns; larger and longer period winter waves have already been observed and may be a growing trend.²³

OCEAN AND COASTAL RESOURCES IMPACTS DUE TO PRECIPITATION CHANGES

- Higher Runoff and Flooding
- Flood Risks from Inland and Coastal Flooding
- Contamination from Sewage Distribution and Treatment Systems
- Health Risks from Contaminated Runoff
- Increased Marine Pollution

C. Sea-level rise

Coastal Flooding and Permanent Inundation

California's coast is home to major population centers, many of which are situated in low-lying floodplains. Large numbers of people and important assets will be increasingly at risk from inundation during coastal storms as higher sea levels, high tides, storm surges, and inland flooding coincide.²⁴ Some low-lying areas will also be permanently inundated unless they are protected. Increasing rates of coastal erosion, beach loss, salinity intrusion into estuaries, and saltwater intrusion into groundwater will need to be addressed in future coastal land management decisions.

Figure 12: Vulnerability of California coastal areas to sea level rise



Source: Kahrl
and Roland-
Holst, 2008

Given the extent of high-value development already located in at-risk flood zones, California's coastal cities are not only at risk from storm-related inundation and flood-related damages, but also permanent property loss where land is eroded or constantly inundated. Currently, over 260,000 Californians live in areas designated as at-risk in a 100-year flood event (a one percent chance of occurring every year).²⁵ What we currently define to be the 100-year flood today will occur much more frequently as sea level rises; therefore, the number of people exposed to risks from 100-year floods will increase substantially as a result of sea-level rise in coming decades.²⁶

Studies indicate that a 1.4 m (~5 feet) rise in the level of the San Francisco Bay by 2100 would place 33 percent more land at risk from flood-related inundation than is at risk today.²⁷ Without accounting for future growth and land use change, the amount of developed land at risk in the Bay area could more than double from current levels by the end of the century.²⁸ A majority of the structures at risk in that region are designated as residential property. The initial estimates of development in San Francisco Bay in 2100 indicate that over \$62 billion worth of building and contents could be at risk.²⁹

On the open ocean coast, challenges are similarly daunting. For example, the City of Santa Cruz has a levee system that protects some low-lying parts of the city against a 100-year flood. With a sea-level rise of approximately one foot, the anticipated 100-year flood event in Santa Cruz is expected to occur every 10 years, increasing the likelihood of storm-related inundation.³⁰ Over the entire California coast, over \$100 billion worth of assets (buildings and contents) would be at risk from a 100-year flood in 2100 assuming a 1.4m (~5 feet) rise in sea level.³¹

Providing insurance coverage for coastal development under even a moderate sea-level rise scenario will be costly. One study estimated that the National Flood Insurance Program (NFIP), which provides

backing for flood insurance in participating U.S. communities, will be confronted with an increase in insured property by 36 to 58 percent for a one-foot rise in sea level; and by 102 to 200 percent for a three-foot rise.³² Not accounting for development and growth, this older study is indicative of the growing flood risk due to sea-level rise alone. The Federal Emergency Management Agency (FEMA) and the national treasury will more often be tapped to deal with growing flood damages in coastal areas unless insurance rates are increased to keep the program actuarially sound.

In addition to private property at risk, infrastructure is also at great risk from coastal flooding and erosion (see the Infrastructure chapter). A complex network of highways and roads, large ports, numerous airports, water supply canals, wastewater treatment facilities, and power plants are located in coastal areas, sometimes directly in floodplains, to support the region's and the state's economy and growing population. This coastal infrastructure is vulnerable to increased heat and flood events, potentially limiting the ability to deliver vital public services.

Impacts on transportation systems will include flooding of roads, railways, transit systems, and airport runways in coastal areas because of rising sea levels and higher storm surges. A substantial amount of ground transportation infrastructure is predicted to be at risk from sea-level rise by 2100, including 2,500 miles of roads and rails.³³ Such infrastructure is vital to the state's economy for both the movement of commercial freight and the ability of Californians to get to work and school. In the San Francisco Bay, the major airports of San Francisco and Oakland are near sea level and would require additional elevation, protection, or relocation to remain functional.

Municipal and industrial infrastructure would be directly and indirectly at risk from alteration of coastal resources due to climate change. Accelerated sea-level rise and storm-related flooding (from the coastal and the inland side) could threaten California's vital but aging levee and water transport system.³⁴ Additionally, water backflow could impair coastal water sanitary sewage systems during flood events.³⁵ Inundation of coastal infrastructure can also cause widespread pollution and contamination, jeopardizing marine and near-marine environments.

OCEAN AND COASTAL RESOURCES IMPACTS DUE TO SEA-LEVEL RISE

- Increased Risks of Coastal Flooding in Low-Lying Areas
 - More People and Assets - At Risk
 - Public Infrastructure - Increased Risk of Inundation
 - Levees and Structures - Require Retrofit
 - Coastal Wetlands - Potential Loss
- Increased Erosion of Beaches, Cliffs and Dunes
 - Private Property and Structures - At Risk
 - Beach Recreation and Tourism - May Decrease in Select Areas
 - Greater Expenditures for Beach Maintenance
- Increased Saltwater Intrusion into Coastal Groundwater Resources
 - Agricultural Land - Degraded by Saltwater

Wetland Loss and Habitat Degradation

Increasing sea levels will submerge many low-lying portions of California's coastal wetlands. Of particular concern are coastal salt marshes, which have already been decreased by 91 percent from historical levels.³⁶ If vegetation and sediment accretion occurs rapidly, wetlands could maintain their present location and the wetland footprint would not decline. For example, while some very high accretion rates occur in the San Francisco Bay region (i.e., up to 80 mm per year), the average rate is approximately 1-2 mm per year. This rate has kept pace with recent sea level rise, but will likely fall short of the projected future sea-level rise of 2-3 mm (or more) per year.³⁷ The high degree of development and infrastructure placed in near-shore areas restricts the inland migration of wetlands in many locations, thus more coastal wetlands are likely to be lost.³⁸

If wetlands are submerged by rising water levels, one consequence would be that wave energy would be less attenuated and erosional forces against upland levees, such as within San Francisco Bay, would increase.³⁹ Additional potential impacts to wetlands due to sea-level rise include: changes to estuarine mixing, water quality, and carbon cycling; changes to upland habitats and sediment loads into downstream wetlands; and changes to wetland biological habitat, diversity, and changes in biological distribution which will potentially impact foraging opportunities and rearing habitats for key ocean species.⁴⁰ Furthermore, the degradation of sensitive ecosystems can be brought about not just by higher sea levels but also by other climate changes, including increased water and air temperatures and changes in precipitation patterns, which together can increase the abundance of invasive species. Changes in the abundance and distribution of critical native species can also have cascading, significant effects on sensitive coastal and ocean habitats.

Increased Coastal Erosion

In addition to coastal flooding, the rate of coastal erosion will also increase as a result of sea-level rise. Loss or movement of beach sand and increased cliff and bluff erosion would jeopardize the stability of many coastal developments and recreation areas. The extent of this impact on California's coastline will vary by the type of coast, the width of the beach, and the presence or absence of protective structures. Damage to coastal infrastructure will be more severe where extreme wave conditions combine with elevated sea levels to impact unprotected and/or erodible coastal areas.

The U.S. Geological Survey (USGS) has developed a preliminary map in 2000 classifying areas of the U.S. Pacific coast based on their physical vulnerability to coastal change due to sea-level rise. Areas classified as "very high" risk are those that have already experienced significant erosion problems, and are concentrated mainly around the state's major bays including the Humboldt, San Francisco, and Monterey Bays as well as Los Angeles and San Diego.⁴¹

Increased coastal erosion will impact private property owners and beach-dependent sectors of the state's economy. Beach recreation and tourism generate the largest economic value of all economic sectors in the California coastal zone.⁴² The economic value of beach recreation and tourism is of particular importance in southern California, as expenditures in just three counties in southern California accounted for 44 percent of the state's total tourism-related spending in 2007.⁴³ Many of the state's intensively used beaches are backed by seawalls, bulkheads, roads, parking lots, or other infrastructure, which prevents landward migration. These beaches will gradually be inundated or will be reduced in width as sea level rises, translating into a reduction on beach area. These physical effects of climate change could significantly decrease the viability and attractiveness of coastal tourism locations, including a shift in tourist attendance patterns among local beaches.⁴⁴ Such changes would generate either direct or transitional costs for the expanse of tourism-related businesses within the service economy of coastal California. The incidence of beach erosion and accretion at individual California beaches indicates a net negative effect from both gradual sea-level rise and extreme events on the order of an \$8.6 million loss in total annual expenditures and a \$36.7 million decline in consumer surplus. However, these impacts will vary regionally. In addition to economic impacts associated with the loss of beaches, the ecological impacts will be significant as California beaches support hundreds of organisms, act as buffers to interior habitat during storms, and are essential for the persistence of rare dune habitats.

According to one recent study for southern California, erosion rates are expected to accelerate by 20 percent for a sea-level rise of 39.4 inches (100 cm).⁴⁵ Several alternatives exist to deal with rising sea level and the issues of coastal erosion and inundation: armor, nourishment, and a planned retreat. Each will have tradeoffs in terms of impacts and costs, dictated by the magnitude of sea-level rise that is expected and the amount of property, infrastructure, or public resources threatened. Creating protective structures can limit or alter the functioning of natural habitats, which in turn can decrease the overall adaptive capacity of coastal ecosystems. Ten percent (or 110 miles) of the entire coast of California is now armored, and 33 percent of the shoreline of the four most southerly California counties has been hardened. We can expect more applications and pressure on permitting agencies (local governments as

well as the Coastal Commission) to approve additional hardened structures in the future as sea level continues to rise.

Saltwater Intrusion

Sea-level rise and changes in the intensity of storm events could impact low lying coastal areas and result in the loss or inundation of coastal wetlands and dune habitat resulting in salt water intrusion and loss of fresh water resources for fish and wildlife. Sea-level rise will also adversely affect coastal water supplies through saltwater intrusion into coastal aquifers, potentially increasing the need for other water sources (such as desalination) to address coastal water shortages and impact groundwater resources tapped for irrigation.⁴⁶ Compounding the problem, low-lying farmland such as the Oxnard Plain and the Bay-Delta region may also be inundated with salt water.⁴⁷

Ocean Acidification

Coastal ecosystems and the industries that depend upon them are being significantly impacted by increased acidification of the ocean due to increases in atmospheric CO₂ concentrations. Globally, the ocean absorbs 30-50 percent of the annual emissions of CO₂.⁴⁸ As CO₂ is dissolved into ocean and estuarine waters, carbonic acid is formed lowering the pH of the water. This increased acidity can hamper the ability of a wide variety of marine organisms ranging from coral to abalone to form calcium carbonate shells and skeletal structures.

Acidification limits the growth and survival of species such as crabs, sea urchins, abalones, oysters and significant plankton species that have calcium carbonate shells and skeletons. The decreased survival of these calcifying organisms has rippling impacts on species that feed upon them (e.g., the loss of key plankton species will negatively impact the salmonids, seabirds, and other species that feed on them). Commercially important shellfish species are likely to be negatively affected: under a moderate emissions scenario (750 ppm CO₂ by 2100), calcification rates of mussel and oyster species are predicted to decline by 25 and 10 percent, respectively, by the end of the century.⁴⁹ The declining pH levels also impact fertilization, development, and metabolic function of many marine species including kelp, which is an essential component of productive coastal ecosystems on the West Coast, and a commercially harvested species. Acidification also affects the toxicity of a variety of substances and the biological availability of important nutrients and other compounds.

D. Risks for Ocean and Coastal Resources

To summarize the changing risks that California's ocean and coastal resources may be facing from climate change, the likelihood of occurrence of the projected consequences was qualitatively assessed. The resulting risk profile for California's oceans and coastal areas can be characterized as follows:

- Sea-level rise will increase the risks of coastal flooding in low-lying areas, inundating private property more frequently and exposing more people and more assets to flooding risks. Infrastructure, public facilities and industrial sites will also experience growing flooding risks. Levees, protective structures, and development may need to be elevated and flood-proofed to maintain protection.
- Threats to coastal wetlands are increasing. If wetlands cannot migrate inland due to man-made or natural barriers, wetland habitat will be lost.
- Sea-level rise will increase erosion of beaches, cliffs, and bluffs, threatening public and private property and structures and causing social, economic, and resource losses to coastal recreation and tourism through reduction in or damage to beaches, access ways, parks, trails, and scenic vistas.
- Loss of wetland, beach, and other coastal habitat will negatively impact many fish, bird, and other species, and diminish biodiversity.

- Californians are likely to experience a more moderate increase in average temperatures in coastal areas than in inland areas due to the cooling effect of the ocean, yet may suffer disproportionately from extreme heat waves.
- Warmer water temperatures will cause shifts in the distribution of coastal and marine species; southern species may extend their range northward. Additionally, exotic species may become invasive in new areas and new pathogens may appear. Together with other climate-driven changes in wind patterns, upwelling, nutrient availability, and hard-to-predict changes in the marine food web, warmer water temperatures may cause recreational and commercial fishing species to decline in abundance or shift their range, leading to widespread economic impacts on these fisheries.
- Fewer, but possibly more intense, rainstorm events will produce high runoff and flooding. In the immediate coastal areas, such inland flooding may coincide with coastal flooding, posing particularly high risks to communities and structures in coastal floodplains.
- High runoff may overwhelm storm drains and sewage treatment plants, potentially contaminating coastal ecosystems and beaches.
- Sea-level rise will increase saltwater intrusion into coastal aquifers (groundwater resources), degrading agricultural land and coastal groundwater resources.
- Rising temperatures and ocean acidification have the potential to negatively impact ecosystems and fisheries.

Ocean and Coastal Resources Adaptation Strategies

Introduction

The state agencies in the Coastal and Ocean Working Group (Ocean Protection Council, California Coastal Conservancy, California Coastal Commission, State Lands Commission, Department of Fish and Game, State Parks, and the Bay Conservation and Development Commission) contributed to the development of the following strategies and each organization will be essential to the successful implementation of the strategies. Given the extent of the threats predicted by current climate models, sea level projections, and the considerable value of California's coastal lands, resources, and development, coastal planning must adapt to prepare California for a variety of potentially significant outcomes of climate change. Preparing California's coastal infrastructure, industries, and ecosystems for the impacts of climate changes will be an expensive endeavor. Decision-makers will need to make short- and long-term risk-management decisions to address future impacts that will include deciding which human developments should be maintained, retrofitted, and protected; where hazard avoidance is not possible; where planned retreat is appropriate; and where natural systems should be protected, rehabilitated, or enhanced.

These decisions should be made using the following principles for guidance:

- California must protect public health and safety and critical infrastructure.
- California must protect, restore, and enhance ocean and coastal ecosystems, on which our economy and well being depend.
- California must ensure public access to coastal areas and protect beaches, natural shoreline, and park and recreational resources.
- New development and communities must be planned and designed for long-term sustainability in the face of climate change.
- California must look for ways to facilitate adaptation of existing development and communities to reduce their vulnerability to climate change impacts over time.
- California must begin now to adapt to the impacts of climate change. We can no longer act as if nothing is changing.

Adaptation to sea-level rise drives most of the Ocean and Coastal Resources adaptation strategies presented in this report. The priority strategy is for state agencies to avoid establishing or permitting new

development inside future hazard zones in most cases if new protective structures would be necessary (strategy 1a). Additional strategies include (1) directives to promote innovative approaches to redesigning coastal structures, where feasible, that are resilient to the impacts of climate change and can serve to protect existing development in low-lying areas (strategy 1b), and (2) creation of statewide guidance and regional planning forums to help local governments update local plans and make planning decisions in light of sea-level rise (strategies 2a and 4c).

All levels of government are encouraged to consider:

- Incentive programs to encourage property owners in high-risk areas to relocate or limit future development.
- Clustering new development in areas considered to have a low vulnerability to sea-level rise.
- Creating additional buffers and setbacks for new construction to minimize risks to people and property and to protect coastal resources such as natural habitat and recreational areas (see strategy 4c).

Critical coastal and ocean habitats and recreational areas should be protected and maintained to the extent feasible. The state should identify priority conservation areas and recommend lands that should be considered for acquisition and preservation, especially vulnerable shoreline areas containing critical habitat or opportunities for habitat creation (strategy 1c). Future sea-level rise estimates should be considered during restoration efforts (i.e., grading levels for wetland restorations), and natural shoreline enhancements (e.g., species such as native oysters, eelgrass) should be designed to promote sedimentation and protect against shoreline erosion.

Adaptation Strategies and Actions

The Coastal Adaptation Working Group has identified the following priorities in addressing climate adaptation for California state agencies. The near-term actions referenced below are those actions that have been identified and which can be initiated or completed by 2010, if, in some cases, related statutory or regulatory changes are made. The long-term actions include those that will require support from that state and collaboration with multiple state agencies or that require significant legal or regulatory changes.

Strategy 1: Establish State Policy to Avoid Future Hazards and Protect Critical Habitat.

Near -Term Actions:

- a. **Hazard Avoidance Policy** – State agencies should consider project alternatives that avoid significant new development in areas that cannot be adequately protected (planning, permitting, development, and building) from flooding or erosion due to climate change. The most risk-averse approach for minimizing the adverse effects of sea level rise and storm activities is to carefully consider new development within areas vulnerable to inundation and erosion, and to consider prohibiting development of undeveloped, vulnerable shoreline areas containing critical habitat or opportunities for habitat creation. State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea-level rise, storm surges, or coastal erosion during the expected life of the structure. However, vulnerable shoreline areas containing existing development or proposed for new development that has or will have regionally significant economic, cultural, or social value may have to be protected, and in-fill development in these areas should be closely scrutinized. State agencies should incorporate this policy into their decisions, and other levels of government are also encouraged to do so. Some state agencies already base decisions on hazard avoidance, for example Coastal Act provisions require that new development in the coastal zone be designed to minimize risks from current and future hazards, which would include

risks from expected sea-level rise, the Act restricts new development in hazardous areas, especially if it would require the construction of a protective device.

- b. **Innovative Designs** – If agencies do plan, permit, develop or build any new structures in hazard zones, agencies should employ or encourage innovative engineering and design solutions so that the structures are resilient to potential flood or erosion events or can be easily relocated or removed to allow for progressive adaptation to sea level rise, flooding, and erosion.
- c. **Habitat Protection** – The state should identify priority conservation areas and recommend lands that should be considered for acquisition and preservation. The state should consider prohibiting projects that would place development in undeveloped areas already containing critical habitat, and those containing opportunities for tidal wetland restoration, habitat migration, or buffer zones. The strategy should likewise encourage projects that protect critical habitats, fish, wildlife and other aquatic organisms and connections between coastal habitats. The state should pursue activities that can increase natural resiliency, such as restoring tidal wetlands, living shoreline, and related habitats; managing sediment for marsh accretion and natural flood protection; and maintaining upland buffer areas around tidal wetlands. For these priority conservation areas, impacts from nearby development should be minimized, such as secondary impacts from impaired water quality or hard protection devices.

Long -Term Actions:

- d. **Coordinate Policy Implementation** – State agencies should use outreach and incentive programs to promote hazard avoidance policies and sound management decisions for coastal habitat protection and development to all levels of government.

Strategy 2: Provide Statewide Guidance for Protecting Existing Critical Ecosystems, Existing Coastal Development, and Future Investments

Significant and valuable development has been built along the California coast for over a century. Some of that development is currently threatened by sea-level rise or will be threatened in the near future. Similarly, the coastal zone is home to many threatened or endangered species and sensitive habitats. We must acknowledge that the high financial, ecological, social and cultural costs of protecting everything may prove to be impossible; in the long run, protection of everything may be both futile and environmentally destructive. Decision guidance strategies should frame cost-benefit analyses so that all public and private costs and benefits are appropriately considered.

Near -Term Actions:

- a. **Establish Decision Guidance** – The OPC in close coordination with other state resource agencies should develop a statewide framework that can be used by state and local agencies as guidance in preparation of adaptation plans. This guidance should discuss current regulatory and legal frameworks and whether changes are necessary to pursue this approach to adaptation. In addition the OPC should incorporate this new guidance within existing decision-making processes as much as possible and tailor it, when necessary, to specific regional approaches (see strategy 4c)..

It should consider three key questions for helping to design and locate proposed or existing structures that may be threatened by sea-level rise:

1. Is the existing or proposed structure either necessary for the health, safety, or welfare of an entire region, or is it located within a hazard area for which protection will be provided because of surrounding high-value development?
2. Is it infeasible to relocate an existing structure or site a new structure outside the hazard area and still provide this health, safety, or welfare function?

3. Will relocating an existing or proposed structure provide habitat protection or recreational opportunities that may be otherwise lost if that structure is built or is protected along the coast?

Additional questions that should be considered in the preparation of the framework include:

- Is there a feasible "soft" protection solution (i.e., can a barrier beach or wetland be used instead of a seawall)?
- Will the protection approach, retrofit, or new design:
 - i. Be necessary to protect an existing structure threatened by erosion?
 - ii. Allow continuation of important natural processes, such as littoral drift, and avoid any impacts to neighboring habitats or structures?
 - iii. Result in the loss of state tidelands or beaches?
 - iv. Provide a long-term solution to the threats caused by sea-level rise?
 - v. Be resilient over a range of sea-level rise possibilities?
 - vi. Provide broad protection to existing developed areas?
 - vii. Protect structures of high cultural or social value?
 - viii. Provide for a natural shoreline (i.e., can seawalls be designed to include habitat)?
 - ix. Be coordinated with proposed actions for other infrastructure in the same flood hazard area?
 - x. Cost less than the value of the structure to be protected?
 - xi. Provide mitigation for adverse impacts that cannot be avoided?

Long -Term Actions:

- b. **Pilot Studies** – Develop pilot studies in cooperation with specific cities/state agencies that will examine the efficacy and utility of the framework highlighted above.

Strategy 3: State Agencies Should Prepare Sea-Level Rise and Climate Adaptation Plans

Near -Term Actions:

- a. **Adaptation Planning** – By September 2010 state agencies responsible for the management and regulation of resources and infrastructure subject to potential sea-level rise should prepare agency-specific adaptation plans, guidance, and criteria, as appropriate. Agencies with overlapping jurisdictions in the coastal zone will coordinate when drafting these plans to reduce or eliminate conflicting approaches.
 - i. The Coastal Commission, the San Francisco Bay Conservation and Development Commission, the state and Regional Water Quality Control Boards, California State Parks, and the State Lands Commission should continue to develop adaptation strategies that can be implemented through their existing planning and regulatory programs.
 - ii. The Coastal Conservancy, the Ocean Protection Council, and the Wildlife Conservation Board should continue to develop criteria to guide their financial decisions and ensure that projects are designed to consider a range of climate change scenarios.
 - iii. The California Department of Transportation, State Parks, the Department of Water Resources, the Department of Fish and Game, the State Lands Commission, and other state agencies that own land and facilities along the coast should develop policies to guide them in land-use projects and the development of infrastructure in vulnerable areas in the future.
 - iv. The aforementioned agencies should:
 - a. Consider requiring applicants to address how sea-level rise will affect their project, include design features that will ensure that the project objectives are feasible and that the project will not be rendered unusable or inoperable over its lifespan, that critical habitat is protected, and that public access is provided, where appropriate.

- b. Prepare climate strategies, indicators, and thresholds that respond to changing ocean temperatures, air temperatures, predator-prey interactions, and ocean acidification. These strategies should include alternative management strategies that could be employed, such as alternative fisheries management approaches dependent upon temperature regimes, alternative marine protected areas for stressed species, or changes to aquaculture and fishing practices under lower pH conditions.
- c. Identify areas where their jurisdiction and authority should be clarified or extended to ensure effective management and regulation of resources and infrastructure subject to potential sea-level rise.
- v. The Department of Insurance should develop regulatory policies to guide private insurers in dealing with properties in vulnerable areas.

Long -Term Actions:

- b. **Adaptation Plan Updates** – State agencies should regularly update, modify, and refine these adaptation guidance documents and plans based on new information and lessons learned from previous implementation actions.

Strategy 4: Support Regional and Local Planning for Addressing Sea-Level Rise Impacts

Near -Term Actions:

- a. **Public Outreach** – The Ocean Protection Council (OPC) in close coordination with other state ocean resource agencies should (beginning in 2010) conduct public meetings within coastal communities to examine adaptive strategies available to state and local agencies to prepare for potential sea-level rise impacts. Strategies, tools, and information will be compiled and made publically available for use by local governments when updating their local and general plans.
- b. **Funding Mechanisms** – The OPC should collaborate with state agencies to identify potential funding sources (i.e., AB32 or an amendment to Prop 218) for state agencies and local governments to undertake revisions to local plans.
- c. **Regional Coordination** – The state should work with local governments and existing regional organizations, such as the Los Angeles Regional Collaborative for Climate Action and Sustainability, associations of local governments, or SB 375 regional planning teams, to provide for regional adaptation planning. The state should continue to conduct, synthesize, and disseminate regionally relevant research and information with this purpose in mind.

Shoreline and land use planning should be informed by regional and sub-regional level considerations. Shoreline dynamics must be understood within the context of discrete littoral cells and other natural systems. In addition, geography, development patterns, and tectonic forces differ a great deal regionally; and the success of alternatives to respond to the challenges of sea level rise and coastal hazards will depend, in large part, on these regional differences. In addition, numerous strategies when implemented may have consequences for neighboring habitats or communities, and coastal communities should have the ability to jointly plan for impacts to the full region to reduce mutually unbeneficial approaches. Developing regional information and understanding regional consequences of various adaptation options will be useful to location governments as they update individual local coastal plans or general plans within a region.

- d. **Local Government Guidance** – All relevant state agencies should collaborate with local jurisdictions to encourage them to consider the following strategies when updating plans:
- i. **Setbacks** – Mandatory construction setbacks can be imposed to prohibit construction and significant redevelopment in areas that will likely be impacted by sea-level rise within the life of the structure.
 - ii. **Additional Buffer Areas** – Additional buffer areas can be established in some places to protect important cultural and natural resource assets.
 - iii. **Clustered Coastal Development** – Coastal development can be concentrated in areas of low vulnerability and may reduce carbon emissions from transportation.
 - iv. **Rebuilding Restrictions** – Rebuilding can be restricted when structures are damaged by sea-level rise and coastal storms.
 - v. **New Development Techniques** – Building codes can be amended to require that coastal development incorporate features that are resilient to sea-level rise (e.g., require that development begin on the second floor).
 - vi. **Relocation Incentives** – Federal, state and local funding or tax incentives to relocate out of hazard areas.
 - vii. **Rolling Easements** – Policies and funding to facilitate easements to a) relocate developments further inland, b) remove development as hazards encroach into developed areas, or c) facilitate landward movement of coastal ecosystems subject to dislocation by sea-level rise and other climate change impacts.
 - viii. **Engineering Solutions** – New engineering approaches will need to be applied to ports, marinas and other infrastructure that must be located on the shoreline to maintain their function as the sea level rises.
- The Governor's Office of Planning and Research will provide a guidance document in 2009 to address state land use planning.
- e. **Amend Local Coastal Plans and General Plans to Address Climate Change Adaptation:** By 2011, or within one year after development of the tools or guidance necessary to support such amendments and if funding is secured, all coastal jurisdictions, in coordination with the Coastal Commission, should begin to develop amended LCPs that include climate change impacts; and local jurisdictions around San Francisco Bay should begin to update their general plans, in coordination with BCDC.

Strategy 5: Complete a Statewide Sea-Level Rise Vulnerability Assessment Every Five Years

Long -Term Actions:

- a. **Vulnerability Assessment** – In coordination with all relevant state agencies, OPC should produce a coastal and ocean vulnerability assessment every five years that consolidates and builds upon existing efforts by the California Energy Commission and other agencies. Each new assessment will discuss the most recent knowledge about climate impacts to ocean and coastal resources, inventory coastal natural and man-made assets, and assess what is at risk (including an economic valuation). The data from these assessments should be periodically incorporated into state agency adaptation plan updates (discussed above, 3b).

Strategy 6: Support Essential Data Collection and Information Sharing

Research and data are needed to perform and update vulnerability assessments. Agencies should work in cooperation with federal partners to seek funding for the collection of essential data. The state should continue to establish baseline climate change data and common modeling assumptions so that planning actions in the different agencies are based on common information to the greatest extent possible.

Near -Term Actions:

- a. **High-Resolution Mapping** – The state, in cooperation with federal partners, should immediately fund the collection of high-resolution topography and bathymetry mapping (i.e., LiDAR) to provide elevation information needed as a baseline for monitoring change, for the modeling of flood hazards, and to help identify and document habitats and ecosystems.
- b. **Tidal Datum** – Monitoring on tidal datums should be maintained and expanded, including establishing additional tide gage stations. Tidal datums are used to measure local water levels and can project how global sea-level rise will be experienced at the local scale. These data are needed to determine the mean high tide and other reference points used in regulatory and legal settings.
- c. **Ecosystem Research** – Research should be conducted on potential changes to ocean and coastal ecosystems, and species ranges, which are already changing - resulting in divergence in breeding and feeding behavior. Understanding ecosystem changes will be essential to future management decisions related to fisheries, species protection, and restoration projects.
- d. **Coastal and Wetland Process Studies** – Research should be conducted to understand and model coastal, estuarine, and wetland circulation and sediment distribution and transport. This information is essential to successful wetland and beach maintenance, restoration, and nourishment projects.

Long -Term Actions:

- e. **Decision Support** – The OPC should work with state ocean resource agencies and other appropriate partners (such as academia and nongovernmental organizations) to help provide the necessary data and tools to state and local agencies for decision support to protect development and habitat from sea-level rise.